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ANALYSIS OF OXIDATION BEHAVIOR ON ALLOYS AND SUPER ALLOYS AT 800°C

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ABSTRACT

Elevated temperature oxidation causes deterioration of materials in boiler, gas turbine and other power generating units. Alloys and super alloys are employed due to higher mechanical properties and creep resistance. The comparative analysis of alloys and super alloys were done and find that super alloys are high susceptible at higher temperature oxidation. The elevated temperature oxidation behavior of alloys and super alloys have been estimated by exposing the specimens at 800°C for 50 cycles, heating 60 Minuets followed by one-third cooling in every cycle at ambient condition. The formed oxides were analyzed with XRD and microstructure was studied with SEM for varied oxidation period. The weight change process was applied to know the total mass gain/loss in oxidation of alloys sample and find that super alloys fallowed the parabolic rate law. Finally, an oxidation mechanism that is the main cause of faster degradation under high temperature was established base on results obtained with various alloys and super alloys analysis.

KEYWORDS: Deterioration, High Temperature, Oxidation, Alloys and Super Alloys & SEM & XRD Analysis

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Original Article

INTRODUCTION

Oxidation is a process of deterioration at elevated temperature, which happen when the alloys/super alloys are warming in the existence of excess amount air [1-2]. It is the concrete mode of degradation at high temperature parts in gas turbines, coal fired boilers, gas fire, material heating furnaces, etc [3-4]. During action, gas turbines blades treated with towering thermal stresses and this stresses requirement is fulfilled by using alloys and super alloys material [5].Alloys and super alloys that exhibit excellent slink resistance, mechanical potency and oxidation resistance at elevated temperature [6-9]. Super alloys carry out better oxidation resistance than alloys at high temperature [10-12]. For obtaining enhanced efficiency, it is necessary to develop super alloys that reduces the formation of oxide which deteriorate the substrate material at faster rate [13-16].The experiments have been performed at 800°C, heating 60 minutes followed by cooling at the period of one third hour, for fifty cycles.

EXPERIMENTAL PROCESS

Material Constitution

The dimensions of each specimen 20 x15 x 5 mm^3 were chopping to the piece of material. Specimen refined up to 220 grit with the help of silicon carbide paper after that, powder of alumina was used for super polishing before starting the experimental study.

Table 1: Elements Constitution of Boiler Steels -T-22, SA-213, SA-516, Inconel-600, Inconel-718, Titanium (Grade-5)

Constitution (wt%)	C	Mn	P	S	Si	Cr	Ni	Mo	Fe	Ti
T-22	0.08 0.12	0.30 - 0.60	0.02 Max	0.01 Max	0.20 0.50	8 9.5	0.40 Max	0.85 1.05	Balance	-
SA-213	0.27	0.3-0.6	≤0.03	≤0.03	0.5	1.9-2.0	-	0.871.13	Balance	-
SA-516 Grade70	0.04	0.85 -1.2	≤0.035	≤0.035	0.130.45	-	-	-	Balance	-
Inconel- 600	0.08	-	-	-	-	15.5	76.0	---	8.0	-
Inconel -718	0.034	-	-	-	-	17.8	50.7	2.92	21.07	0.86
Titanium-grade5	0.08	-	-	-	-	-	-	-	0.40	91

Experiments of Oxidation Study

The studies were done in tube furnace having PID temperature controller at 800°C.For providing consistency in reaction, samples were refining for the study of oxidation process. Digital venire caliper was used to compute the dimensions of sample for calculation of surface area. Lastly specimens were removing oil, grease by ethanol and placed at the alumina boat. Experiments were done in total 50 cycles, each cycle specimen heating an hour and cooling one third hour at 800°C under cyclic condition. The comparative study of alloys and super alloys has investigated and find that super alloys are better than alloys. Sample of alloys and high temperature resistive alloys were place inside alumina craft after that fit in furnace. Such samples placed in furnace at 800°C for one hour heating and they were withdraw and frozen at ambient temperature for 20 minutes, after that 0.001 gms sensitivity electronic balance instrument of weight measurement was used. Spelled each of small piece material was also considered which fall into the boat. The weight measurement included the weight of the boat.

RESULTS AND DISCUSSIONS

Visual Examination

The surface morphology of boiler steels T-22, SA-213, SA-516 and Nickel based super alloys Inconel-600, Inconel-718 as well as Titanium grade-5 oxidized in presence of excess amount of air at 800°C for 50 cycles, by heating an hour and followed by cooling 20 minutes are shown in diagram. 3.1. The surface of T-22 shown like fade gray color after 20 cycles and then changes in to medium dark color with some white spots at the end of 50th cycles as shown in diagram 3.1 (a). The light gray color scale appeared on boiler steel SA-213 up to 15th cycle and then changed to light brown color at the end of 50th cycles is publish in diagram.3.1 (b).The oxide color of steel alloy SA-516 remained light black throughout the cyclic study as shown in diagram 3.1 (c). Gray color scale was noticed on Inconel-600 surface after 36th cycle, after that changed to gray color with some white spots lastly of 50th cycles, as can be seen in diagram 3.1 (d). Light gray color scale was noticed up to 17th cycle on Titanium grade-5, and thereafter some small golden color balls scale has appeared on the surface up to finished time as represented by diagram 3.1(e).Fine gray oxide has seen on Inconel-718 surface later than 32th cycles, and then turns in to gray color with some white spots at the end of 50th cycles are publish in diagram. 3.1 (f).

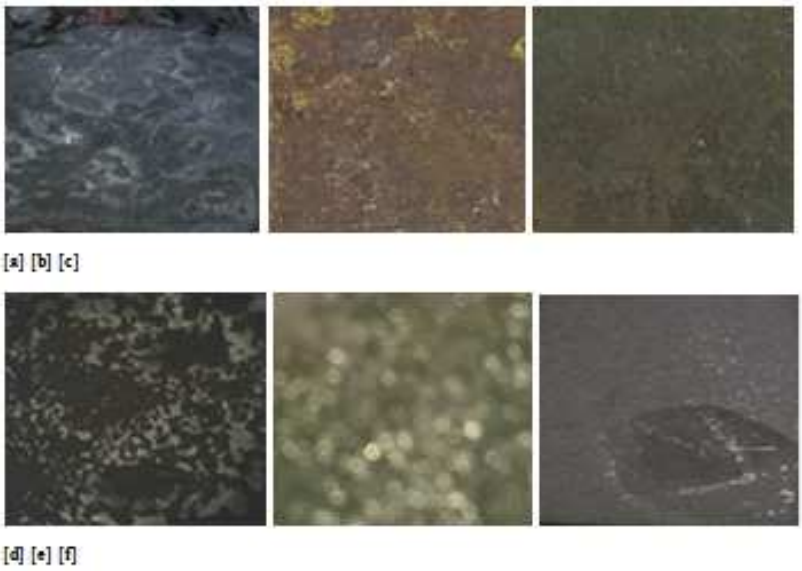

Figure 1: Micrographs of Uncoated Boiler Steel Alloys and Super Alloy oxidized at 800°C (a) Uncoated T-22 (b) Uncoated SA-213 (c) Uncoated SA-516 (d) Uncoated Inconel-600 (e) Uncoated Ti-Grade-5 (f) Uncoated Inconel-718.

Thermo-Gravimetric Data Analysis

The graph of average weight change vs. time (no. of cycles) for boiler steels T-22, SA-213, SA-516 and super alloys Inconel-600, Inconel-718 and Ti-grade 5 oxidized at 800°C are represented in diagram.3.2. Among all boiler steel alloys, SA-213 has showed steep weight gain up to 7th cycles, after that SA-213 showed continuously weight loss up to 36th cycles and then constant up to 50th cycles. T-22 & SA-516 boiler steels has showed approximately same weight gain up to 27th cycles, after that T-22 showed higher weight gain as compared to SA-516 up to 50th cycle. The weight gain for super alloys Inconel-600, Inconel-718 showed negligible up to 18th cycle but Ti-grade5 showed slowly weight gain up to 50th cycles. After 18th cycle Inconel-600 weight gain increases quasi-statically and Inconel-718 find approximately negligible, at the end of 50th cycles. The average weight gain is shown in table 3.1.

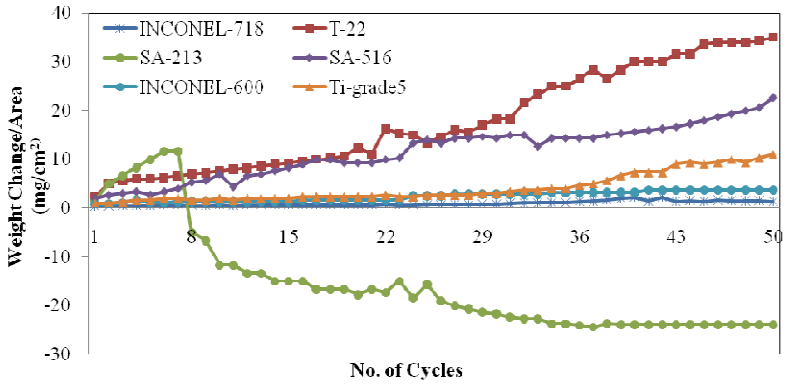

Figure 2: Weight Change Against Number of Cycle's Diagram for Boiler Steels T-22, SA-213, SA-516 and Super Alloys Inconel-600, Inconel-718 and Ti-Grade 5 Subjected to Excess Air at 800°C.

Table 2: The Average Weight Gain for Alloys Subjected to Excess Air for 50 Cycles, at 800^{0}C

S. N.	Name of Substrate Material	Weight Gain (mg/cm^2) 800°C
1	T-22	17.813
2	SA-213	-15.575
3	SA-516	11.606
4	INCONEL-600	2.371
5	INCONEL-718	0.851
6	Titanium grade-5	4.073

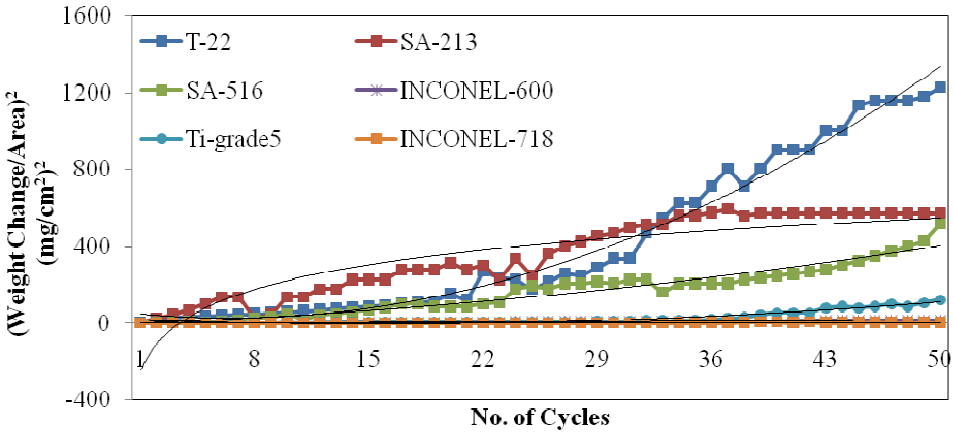

Figure 3: Weight Change Square Versus no. of cycles for Boiler Steels T-22, SA-213, SA-516 and Super Alloys Inconel-600, Inconel-718 and Ti-Grade-5 Treated to Excess Oxygen at 800°C.

The plots for weight gains square/area versus no. of cycles for alloys T-22, SA-213, SA-516, super alloys Inconel-600, Inconel-718 and Ti-grade-5 subjected to high temperature corrosion in rich oxygen at 800°C are indicated in diagram.3.3.The square graph slop showed rate of chemical reaction of oxidation which mentioned in table 3.2.

Table 3: The Average Value of K_p for Alloys Treated in Excess Oxygen at 800°C

S. N.	Substrate Material	Value of $K_p x10^{-8}$ $g^2cm^{-4}s^{-1}$ 800°C
1	T-22	420.58
2	SA-213	355.13
3	SA-516	163.47
4	INCONEL-600	6.09
5	INCONEL-718	0.90
6	Titanium grade-5	24.97

Chemical Kinetics of Oxidation

The kinetics of high temperature corrosion may be described with the assessment of chemical rate constant value K_p, that was calculated by equation:

$$(W2 - W1/lb)^2/t = Kp$$

Where

$(W2 - W1/lb)$= weight change/area

K_p = chemical rate constant,

lb = multiplication of length & breath,

t = freezing period

The graph draw between weight change square with respect to total cycles as displayed in diagram3. Super alloys followed the parabolic law approximately at higher temperature as indicated in diagram. The slop of logarithmic trade lines were indicated the chemical rate constant k_p. The chemical rate constant of alloys were found to be much larger as compared to super alloys.

SEM AND XRD

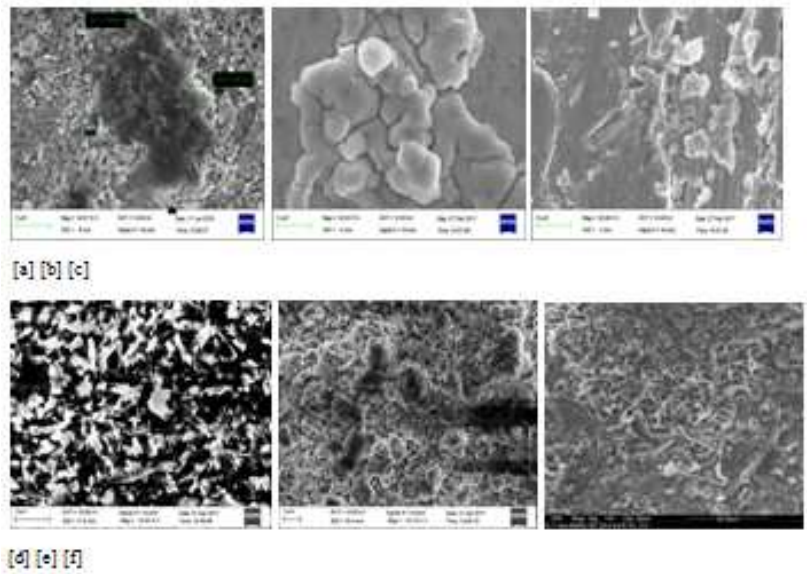

Figure 4: SEM Micrograph, Boiler Steel Alloys (a) T-22,(b)SA-213,(c)SA-516 and Super Alloys (d)Inconel-600, (e)Inconel-718 and (f)Ti-Grade-5 Subjected Presence of Excess Oxygen at 800°C.

The micrograph of uncoated alloys consists of irregular size of the particles. There is also an existence of surface annulled in the morphology. The micrograph of super alloys consists of regular size of particles; such microstructure absorption probability of oxygen is minimum. The formation of chromium oxide & Titanium oxide on super alloys surface have been protected the material at towering temperature corrosion, which is reported by Mishra et al [17].

CONCLUSIONS

The cyclic oxidation of boiler steel alloys T-22, SA-213, SA-516, weight gains were found 17.813,-15.575, 11.606 mg/cm^2 respectively and super alloys INCONEL-600, INCONEL-718, Ti-Grade5, weight gains were found 2.371, 0.851, 4.073 mg/cm^2 respectively. Among all alloys and super alloys, super alloys showed good resistance of oxidation in rich oxygen environment due to low parabolic rate constant K_p.

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